THE PLACE FOR COMPUTATIONAL FLUID DYNAMICS MODELS IN THE OPTIMISATION OF GEOTHERMAL CUTTINGS PONDS.

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ABSTRACT

The geothermal drilling process makes extensive use of drill cuttings ponds for the storage and disposal of drilling fluids and drill cuttings. Generally the local practise is to discharge the drilling fluid to the pond and rely on soakage for the ultimate disposal of the water content.

This practise has a number of drawbacks: the lack of recycling means that the full drilling water supply budget must be sourced from surface water takes, which creates challenges with the ever reducing surface supply options. The existing pond geometry creates deltas of drill cuttings near the outfall, which are difficult to clean out. Finally the ultimate remediation of the ponds becomes challenging when the rig moves on as the Sodium Bentonite in the drilling fluids bind up the underlying soils, reducing soakage to ground, resulting in brine sitting in the ponds for years at a time.

Computation Fluid Dynamics (CFD) models of both a typical pond installation and an optimised configuration were run, comparing the fluid dynamics and the most probable sedimentation profiles between the two.

As a result, a pond design was produced that allowed for easy maintenance, a small change in footprint and shape with the attendant improvement in fluid quality that allows for the extraction of fluids for water recycling, thus reducing the environmental impact of the drilling process.

KEYWORDS

Computational fluid dynamics, CFD, geothermal drilling, cuttings ponds

1 INTRODUCTION

The geothermal drilling process requires significant amounts of water to lubricate the drill cutting head and lift the cuttings from the drilling face. Without a reliable water source, conventional drilling is generally not possible. This water is normally sourced from a local water body and delivered to the drilling pad by pump and rising main. Generally there are strict controls imposed by the regional council as to how much water can be extracted and the geometry of the extraction gantry with respect to stream depth and width. This makes sourcing water one of the more challenging aspects of the civil design portion of the drilling process.

In addition to the above water is required in significant quantities (of the order of 50 l/s for several days at a time) in the event of total loss zones, blind drilling and / or quenching activities.

Water used in the drilling process is returned to the surface carrying the cuttings from the drilling head, with amounts of cement, bentonite clay and a number of viscosity modifying additives to assist in the transport of the cuttings. This fluid is disposed of to a cuttings pond, normally next to the drilling rig itself with the expectation that the fluid will soak to ground.

Cheal's experience with the permeability of tephra / ash and geothermal clay soils on which a significant majority of the recent drill pads have been placed is that permeabilities of 10^{-6} m/s is normal, with occasional soakage rates as low as 10^{-9} m/s. Permeability rates are further reduced by binding of the soils with bentonite and cement, thus producing an effectively impermeable liner in the ponds.

Discharges from the shaker tanks and the cellar drains into the cuttings pond often results in large deltas of coarse grained cuttings that gradually take up significant portions of the pond volume. Their placement next to the rig makes them difficult to remove while drilling operations are under way.

The volume of the ponds is dictated by the Code of Practise for Geothermal Well drilling (the Code). This specifies that the pond should have a volume of 5 times the volume of the well(s) being drilled. (NZ standards 1991)

Photograph 1: Drained pond showing delta of cuttings.

Post-drilling the ponds are allowed to settle and the clear liquid gradually drained from the top of the pond. This process can take several years to complete before the sediment is sufficiently dense to allow blending and capping. This results in open ponds becoming a hazard on site and creates a financial liability in that the budgets to remediate the ponds must be approved and held for the period of consolidation.

1.1 TYPICAL RIG PLAN

The layout of differing drilling rigs and drilling rig operators vary considerably, thus influencing the acceptable pond design. A rig and camp layout for an older 'workover' sized rig was adopted. This is shown in Figure 1 below:

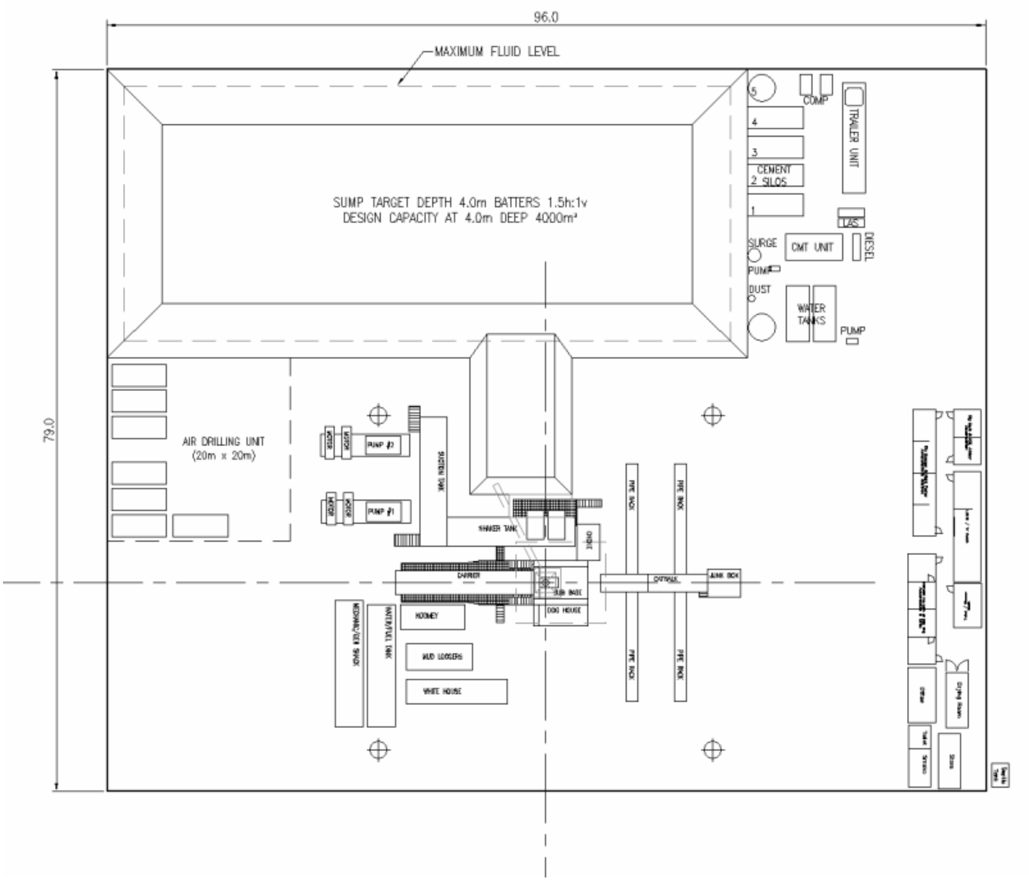

Figure 1: 'Typical' Rig Layout

2 REQUIRED CONDITIONS

The fluid in the pond is largely made up of fluid rejected from the drilling process in the form of wash down, spent drilling mud and some overflow from the cellar during cementing etc. In general the coarser grained materials (stone chips sands and dusts) from the drilling have rapid settling velocities commensurate with their particle sizes. It is assumed that the bentonite and other clays used in the drilling mud, have settling velocities in the order of 1×10^{-6} m/s to 1×10^{-5}m/s. (Edzwald & O'Melia, 1974)(Wu & Wang 2006).

The 'ideal' solution for the ponds would have the following attributes:

- Ease of maintenance for cleanout – preferably all sediment layers should be within reach of a long reach digger without the need to dismantle any parts of the camp or rig
- Ease of water extraction – the 'take' point from the pond should be next to the rig to encourage reuse
- Maximum use of the volume of the pond
- Minimum possible velocity profile to encourage settling of clays.
- Minimum possible cost difference between the existing pond and any optimized solution

3 MODELLING

Computation fluid dynamics (CFD) is a branch of fluid dynamics that uses numerical methods and approximations to calculate fluid flow through (generally assumed to be three dimensional) space. The three dimensional nature and potentially fine grained (depending on mesh size) assessment of fluid velocities allows

CFD models to be used successfully in predicting sedimentation and erosion in fluid domains, such as ponds and reservoirs.

3.1 MODELLING METHOD

Model domains were created using FreeCAD; a parametric modeling software. These were imported into Salome Meca for meshing using the Netgen routine. The meshed models were imported into Code Saturne for CFD modeling.

Models were run using the following parameters:

- Turbulence model – Laminar flow
- Baseline flow 30 litres per second
- Rectangular pond of 80 x 30m with 1:1 wall slopes 4m deep
- Mesh size was 150mm (max) and 10mm (min)
- Fluid properties were those of water (g = 1,000 kg / m3 m = 1.002 x 10^{-3})
- Timestep = 0.05s

3.2 MODEL 1 – EXISTING CASE

An existing case of a single unit pond with the inlet as a single cellar drain and an outlet as a 4m x 4m patch diametrically opposite on the pond floor, imitating soakage.

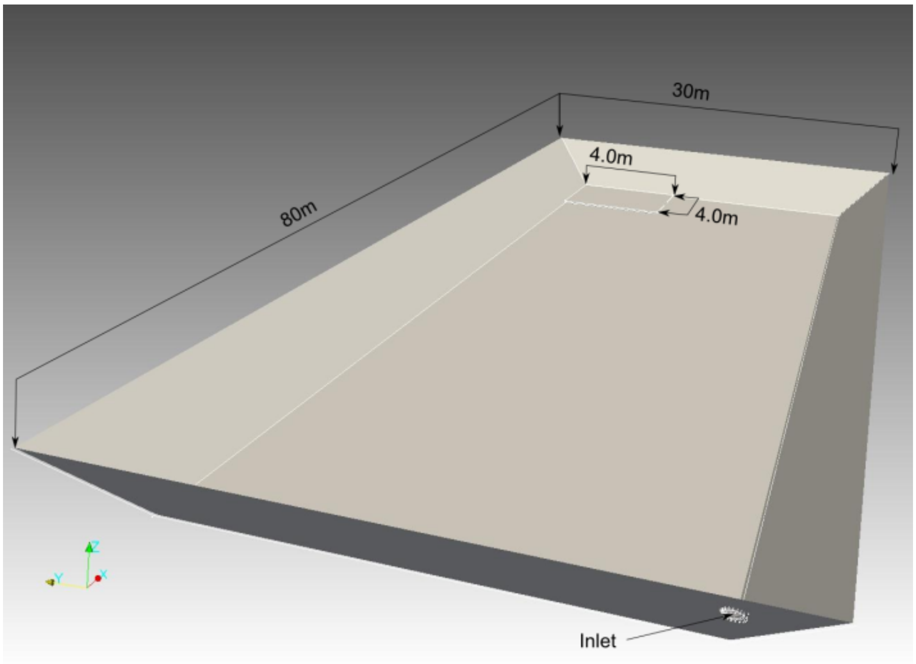

Figure 2: Basic Pond Layout

As can be seen from figure 2 below, the majority of the pond space is ‘dead’ with almost no movement. This volume is effectively wasted and results in a velocity in the ‘stream’ that is, on average, comparatively high.

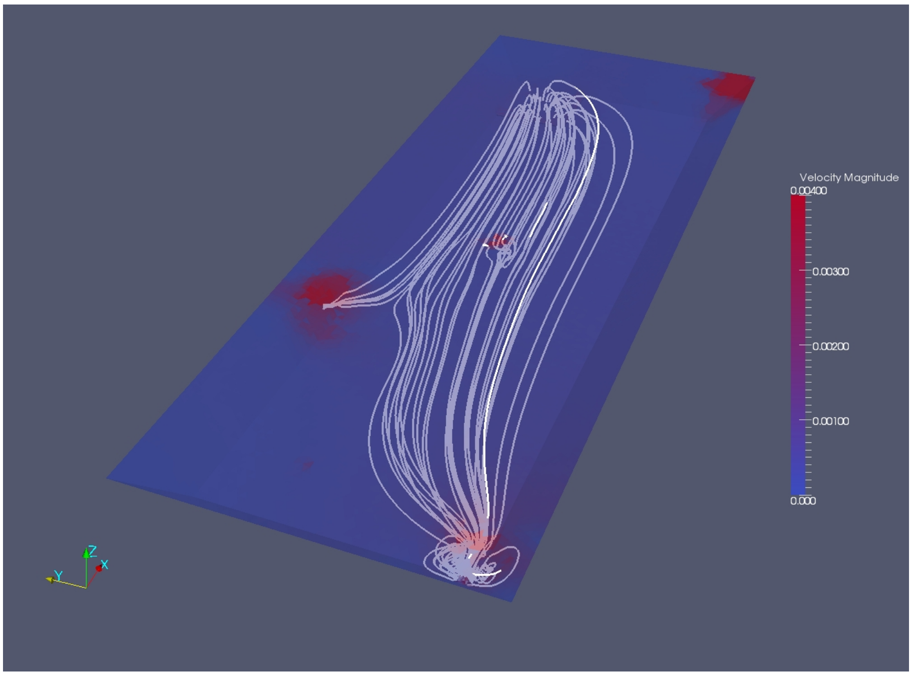

Figure 3: Hydraulics of the Basic Pond

The randomized patches of turbulence throughout the pond mean that it is unlikely that sediments of the clay range will have sufficient chance to sediment rapidly and, if they do, are more likely to be resuspended.

3.3 MODEL 2 – BASIC FOREBAY

From time to time a simple forebay is installed in ponds, using either a short retaining wall or a ‘super silt fence’ type design.

This was modelled using a 200mm wall, transverse to the centerline of the pond, extending 3.4m up from the base stationed 15m from the inlet side wall.

As can be seen from figure 4 below, the transverse forebay structure creates a local area of comparatively high velocity and turbulence. As such the inclusion of this structure is, in fact, a detriment to the sedimentation patterns in the pond.

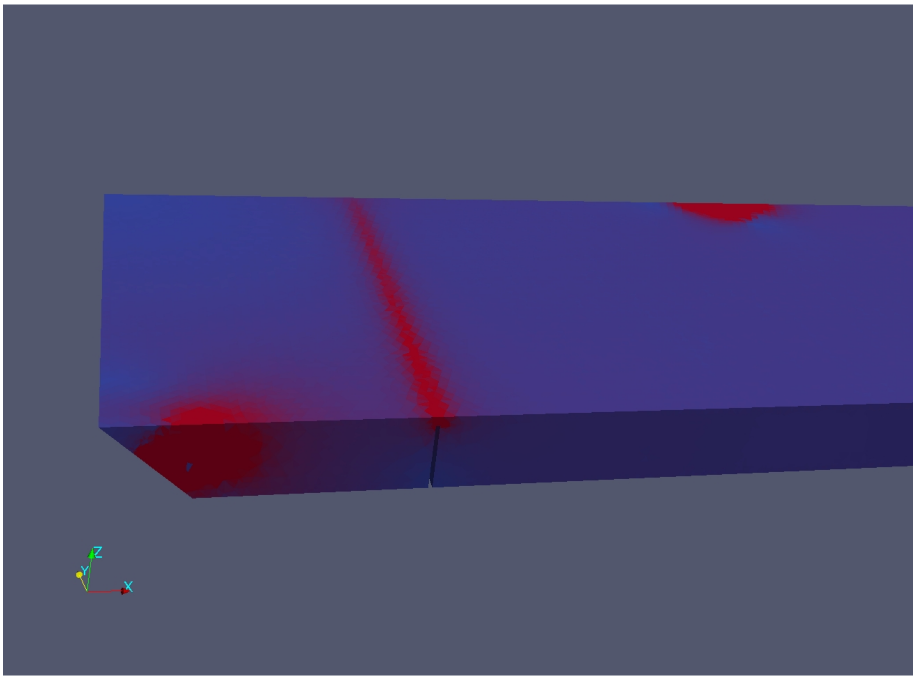

Figure 4: High velocity and turbulence at forebay wall

Counter-intuitively, while this should capture the coarser sediments, the targeted fine sediment that needs to be removed to maximize the use or rapid disposal of water in the pond is carried through with the comparatively high velocities (and turbulence) in the forebay. As can be seen at the top of Figure 4 the randomized patterns of turbulence are still noticeable in the pond volume leading to sediment transport and extended suspension.

3.4 MODEL 3 – IMPROVED FOREBAY

A street arrangement can be formed by rotating the ‘silt fence’ retaining such that instead of being transverse to the flow it is parallel to it, creating a long ‘street’, 10m wide, instead of the normal forebay.

The introduction of the ‘street’ has a significant improvement on the flowlines and velocity, as can be seen in Figure 5, below. This results in a lower overall velocity in the pond, and a better use of the pond volume. The width of the street is within the standard reach of a long-reach digger. The use of one side of the pond, however, is challenging for access if the rig is to occupy that same side.

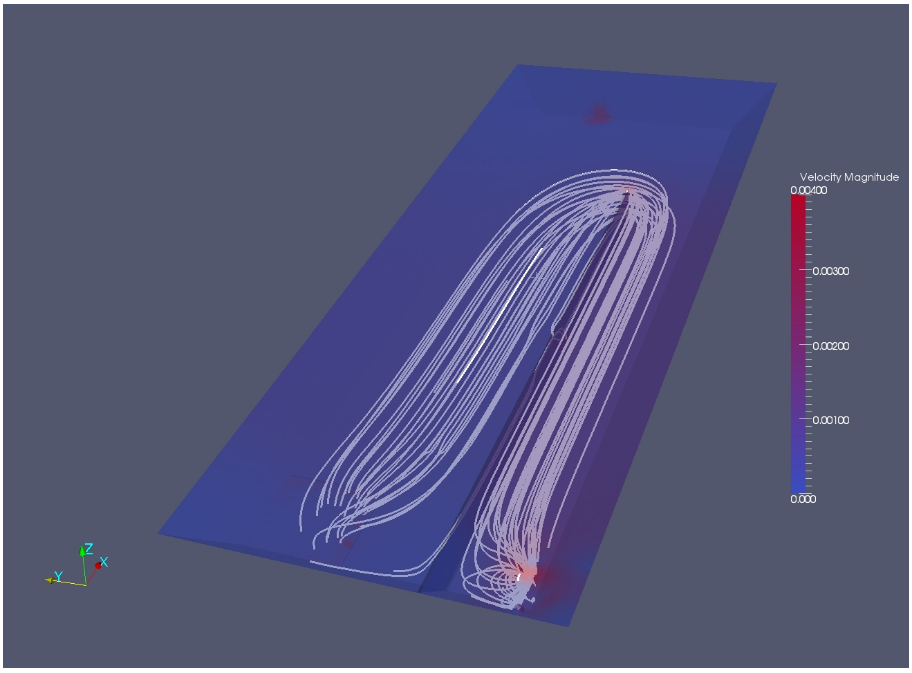

Figure 5: Hydraulics of street layout

3.5 MODEL 4 – IMPROVED FOREBAY AND OPTIMISED POND DESIGN

The location of the shaker tank and the cellar drain sometimes require the creation of an annex next to the pond. This has been taken up in the 'ideal' model. The street outlined option above is extended with the expected outlet location near to the rig site.

The shallow area around the shaker pads has the effect of propagating local turbulence in the fluid. This is actually positive in this location as it allows for flocculent dosing in this area and the mixing of the flocculent through the fluid. The street corners do create some local areas of comparatively high velocity as the fluid is required to change direction but this is offset by the longer 'street'.

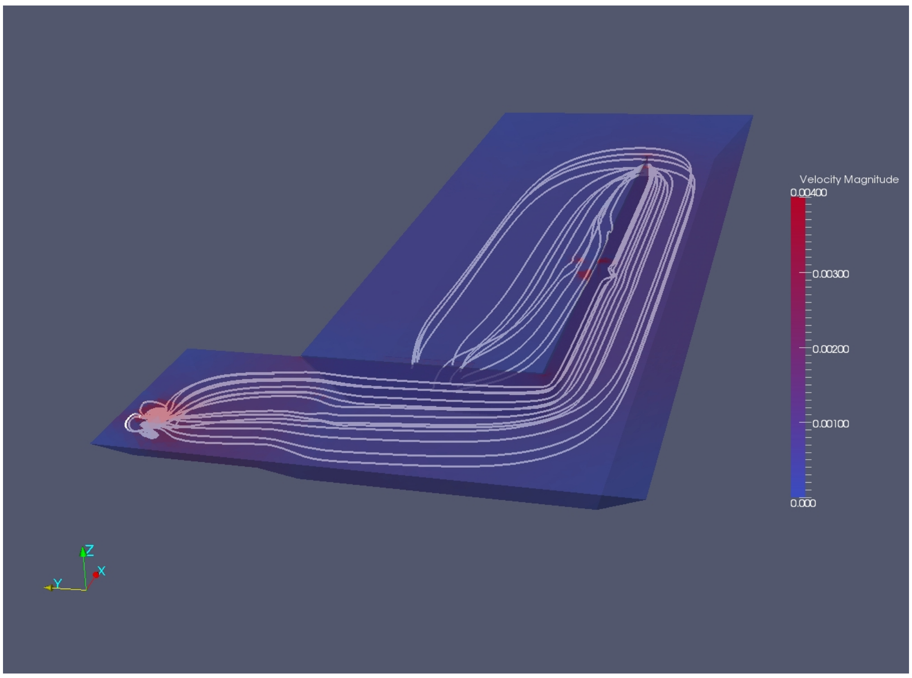

Figure 6: Hydraulics of Ideal layout

As can be seen from this geometry, maintenance can now take place on the side of the pond away from the rig meaning minimal impact on the drilling operations.

4 WATER SUPPLY FROM THE POND

It is unusual for water supply to be sourced from the drill cuttings ponds. Normally, the water is too laced with spent drilling fluid to be acceptable. In the ‘ideal’ case, with either flocculent dosing or a final treatment in the form of a lamella filter or sand filter; water clean enough to be reused could be sourced from the pond at a point convenient to the rig. This water could be used in the case of an emergency for quenching, or could be blended with the incoming water supply to help in the case of a tenuous water supply (as in a small stream).

If the excess water is not required for the rig, since it is cleaner it will soak away more rapidly under its own head or it can be pumped to a soakage pit. The reduction in stored water volume and the structural changes made to allow easier removal of cuttings and mud from the pond could allow the pond size to be reduced. This would be in contravention of the code and would need specific design but would allow a significant reduction in the footprint of the drilling operation, thus allowing for the economic utilization of steeper and / or more marginal sites.

5 OPTIMISED POND COST

The costing for the pond has been assessed using Cheal Consultant Ltd’s database of rates, augmented with Rawlinsons 2011 rate book.

Item	Amount	Unit	Unit Cost	Value
Shaker pad extension – cut to waste	**450**	**m^3**	**$15.00**	**$6,750.00**
Super Silt Fence 4m high	**70**	**m**	**$200.00**	**$14,000.00**
Extra Labour	**1**	**LS**	**$1,000.00**	**$1,000.00**
Total				**$21,750.00**

Table 1: Cost Estimate – structural changes

The above costs are an increment on a total expected pond value of approximately $145,000, giving a total expected cost of $166,750. The value of the changes produces a 13% increase in total costs.

6 APPLICATIONS OUTSIDE OF GEOTHERMAL DRILLING

Computational fluid dynamics techniques can be applied to a significant range of similar fluid bodies. Examples might be stormwater treatment ponds, wastewater oxidation ponds and dams, both hydroelectric and water supply. In each case the movement of fluid through the body and the probable deposition (or transport) of sediment is vital to the optimised and continued operation of the asset.

7 CONCLUSIONS

With some structural changes to the shape of the typical drill cuttings pond, and the application of computational fluid dynamics, it can be demonstrated that the utilization of the ponds can be significantly improved at a minor increase in construction cost.

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